APPENDIX B

CONTROLS/TECHNOLOGIES AVAILABLE FOR INDUSTRIAL SECTOR

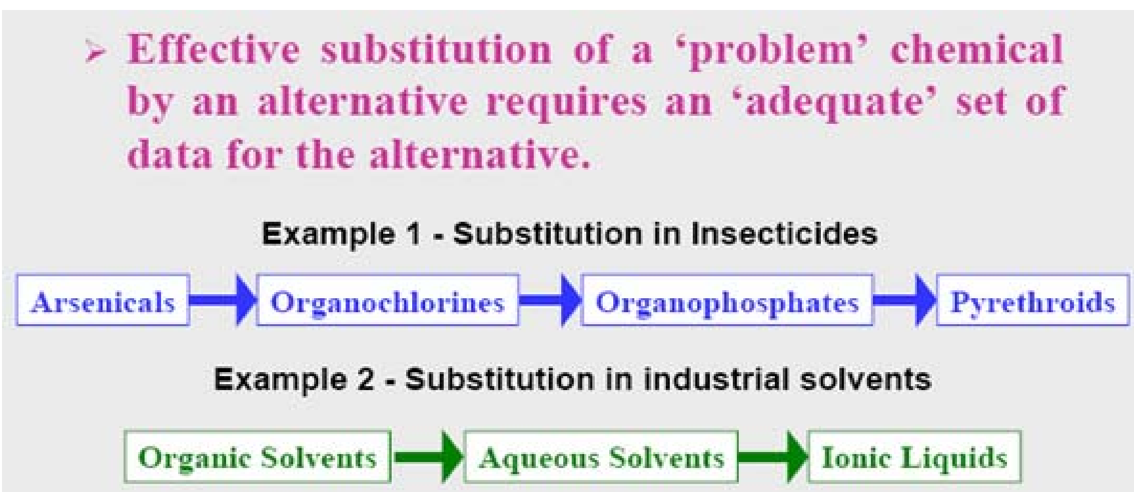
1.) Substitution of Materials with Lower Carbon Dioxide Equivalents

As can be seen on Table 1, global warming potentials can vary greatly with some chemicals having virtually little or no global warming potential. Although not included on the chart, ammonia has virtually zero global warming potential. However, it has significant inherent safety risks associated with handling this material in comparison with materials having a higher global warming potential. So, it is important to consider the chemical being considered from a variety of perspectives including its toxicity, flammability, and reactivity, in addition to its environmental friendliness.

An example of the principle of substitution to reduce carbon dioxide emissions can be found in the production of cement. Switching to lower CO_2 fuels in the cement kiln operation, such as natural gas and agricultural waste (peanut hulls, etc.), can reduce these emissions. Another strategy, which addresses the CO_2 emissions from calcining limestone, is to use waste lime from other industries in the kiln. Substitution of fly ash for some of the cement in concrete can have a very large effect. (www.buildinggreen.com)

As shown in Figure 1 below, substitution also involves developing an in-depth database, review and testing of the material in its proposed use. It will likely also involve process/equipment retrofitting or adaptation. (www.defra.gov.uk)

Figure 1



2.) Utilization of CO_2 Emissions in Process (ww.scielo.php?script+sci arttext&pid+S0100-40421999000200019)

One of the major issues with recovered carbon dioxide is its purity that drives the use. The grade of recovered carbon dioxide depends on the source: carbon dioxide from combustion processes contains impurities of S-compounds, or other organic pollutants (like non-combusted organic compounds, or else molecules generated in the combustion, dioxins and similar compounds) that may prevent its direct use, for example in the food-industry. Other sources (ammonia synthesis, and sugar-fermentation) may provide quite pure carbon dioxide that, in most cases, can be used as recovered with economic advantage. The fermentation industry is particularly indicated as source of pure carbon dioxide to be used in the food-industry.

3.) Carbon Capture (www.fossil.energy.gov)

CO_2 is currently recovered from combustion exhaust by using amine absorbers and cryogenic coolers. The cost of CO_2 capture using current technology, however, is on the order of $150 per ton of carbon - much too high for carbon emissions reduction applications. Analysis performed by SFA Pacific, Inc. indicates that adding existing technologies for CO_2 capture to an electricity generation process could increase the cost of electricity by 2.5 cents to 4 cents/kWh depending on the type of process.

Furthermore, carbon dioxide capture is generally estimated to represent three-fourths of the total cost of a carbon capture, storage, transport, and sequestration system. The program is pursuing evolutionary improvements in existing CO_2 capture systems and also exploring revolutionary new capture and sequestration concepts. The most likely options currently identifiable for CO_2 separation and capture include:

- Absorption (chemical and physical)
- Adsorption (physical and chemical)
- Low-temperature distillation
- Gas separation membranes
- Mineralization and biomineralization

Opportunities for significant cost reductions exist since very little R&D has been devoted to CO_2 capture and separation technologies. Several innovative schemes have been proposed that could significantly reduce CO_2 capture costs, compared to conventional processes. "One box" concepts that combine CO_2 capture with reduction of criteria pollutant emissions are being explored as well. Examples of activities for this program element include:

- Research on revolutionary improvements in CO_2 separation and capture technologies
    - *New materials (e.g., physical and chemical absorbents, carbon fiber molecular sieves, polymeric membranes);*
    - *Micro-channel processing units with rapid kinetics;*
    - *CO_2 hydrate formation and separation processes;*
    - *Oxygen-enhanced combustion approaches;*
- Development of retrofittable CO_2 reduction and capture options for existing large point sources of CO_2 emissions such as electricity generation units, petroleum refineries, and cement and lime production facilities;

4.) Utilization Of Electrically Driven Devices vs. Fossil Fuels Such as Electric or Hybrid Electric/Gas Driven Vehicles (www.epa.gov and www.1eere.energy.gov)

Refer to the “Transportation Sector” of this report for information on vehicle use, emissions, policies, standards, and technologies.

5.) Use of Solar Photovoltaic Devices (www.doe.gov)

Solar water heating systems use solar energy to heat water for residential, commercial or industrial applications. Such systems have been marketed for many years. Many different designs are commercially available. The Oregon Office of Energy, for example, currently has performance values for 77 OG-300 certified and 12 generic system configurations and sizes for the state alternative energy tax credit program. Active systems use a pump to circulate heat-transfer fluids whereas passive systems rely on natural circulation. Open-loop systems circulate potable water directly through the solar collector, whereas closed-loop systems use an intermediate heat-transfer loop between the collectors and a heat exchanger. All systems incorporate freeze protection features when used in climates subject to freezing temperatures.

Building-scale solar photovoltaic systems produce electric power for on-site use and for sale back to the electric grid. These systems may be connected to the utility grid, or stand-alone. Grid connection, where feasible, provides service during periods of insufficient sunlight without storage batteries or an auxiliary generator. In some areas, surplus electricity can be sold back to the utility. The photovoltaic array can be either attached to the building or incorporated into its structure. Rack-mounted systems use arrays of standard photovoltaic modules affixed to roofs or separate supporting structures. Building-integrated systems use building components such as shingles or tiles that incorporate photovoltaic surfaces.

6.) Leak Detection & Repair Programs (www.energystar.gov)

Various methods of screening and measurement techniques are listed in the following table:

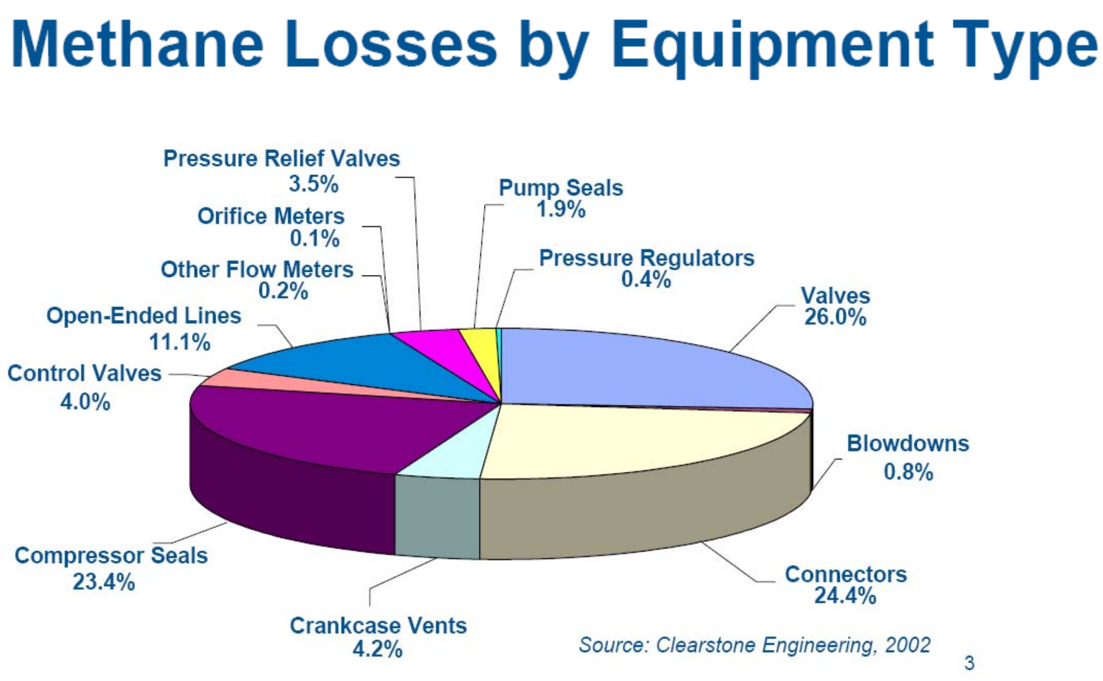
Methane Emissions from Leaking Components			
Component Type	**% of Total Methane Emissions**	**% Leaks**	**Estimated Average Methane Emissions per Leaking Component (Mcf/year)**
Valves (Block & Control)	26.0%	7.4%	66
Connectors	24.4%	1.2%	80
Open-Ended Lines	11.1%	8.1%	186
Pressure Relief Valves	3.5%	2.9%	844

Source: Clearstone Engineering, 2002, Identification and Evaluation of Opportunities to Reduce Methane Losses at Four Gas Processing Plants. Report of results from field study of 4 gas processing plants in WY and TX to evaluate opportunities to economically reduce methane emissions.

Summary of Screening and Measurement Techniques		
Instrument/ Technique	***Effectiveness***	***Approximate Capital Cost***
Soap Solution	* *	$
Electronic Gas Detectors	*	$$
Acoustic Detection/ Ultrasound Detection	* *	$$$
Toxic Vapor Analyzer (FID)	*	$$$
Bagging	*	$$$
High Volume Sampler	* * *	$$$
Rotameter	* *	$$
Infrared Detection	* * *	$$$

*** - Least effective at screening/measurement** **$ - Smallest capital cost**

***** - Most effective at screening/measurement** **$$$ - Largest capital cost**



7.) Energy Efficiency of Processes (www.energystar.gov)

Use of industry best practices for motors, pumps, fans, compressed air, steam, and process heating:

Motors/Pumps/Fans: Motor-driven equipment accounts for 64 percent of the electricity consumed in the U.S. industrial sector. Within the nation's most energy-intensive industries—which are the focus of ITP's Industries of the Future strategy—motor systems consume approximately 290 billion kWh per year. In these industries alone, improvements to motor systems could yield dramatic energy and cost savings. The key to these savings is applying energy-efficiency equipment or implementing sound energy management practices.

Compressed Air: In the U.S., compressed air systems account for $1.5 billion per year in energy costs, and 0.5 percent of emissions. Many industries use compressed air systems as power sources for tools and equipment used for pressurizing, atomizing, agitating, and mixing applications. Optimization of compressed air systems can provide energy efficiency improvements of 20 to 50 percent.

Steam: Over 45% of all the fuel burned by U.S. manufacturers is consumed to raise steam. Steam is used to heat raw materials and treat semi-finished products. It is also a power source for equipment, as well as for building heat and electricity generation. Many manufacturing facilities can recapture energy through the installation of more efficient steam equipment and processes. The whole system must be considered to optimize energy and cost savings. Such as:

- Steam Generation through cogeneration applications, boiler controls, and water treatment

- Steam Distribution through checking steam leaks, installing insulation and proper steam trap maintenance
- Steam End Use through heat exchanger maintenance
- Steam Recovery through condensate return

Process heating: Process heating is vital to nearly all manufacturing processes, supplying heat needed to produce basic materials and commodities. Heating processes consume about 5.2 quadrillion Btu of energy annually, which accounts for nearly 17 percent of all industrial energy use. Advanced technologies and operating practices offer significant savings opportunities for your plant. Find the publications, software tools, and training information you need to get started today.

- Check Burner Air to Fuel Ratios
- Check Heat Transfer
- Furnace Pressure Controllers
- Install Waste Heat Recovery Systems for Fuel-Fired Furnaces
- Load Preheating Using Flue Gases from a Fuel-Fired Heating System
- Oxygen-Enriched Combustion
- Preheated Combustion Air
- Reduce Air Infiltration in Furnaces
- Reduce Radiation Losses from Heating Equipment
- Using Waste Heat for External Processes

8.) Use of Energy-Star Appliances

Further information on the ENERGY STAR© program can be obtained by visiting the following website: http://www.energystar.gov/.

9.) Optimized Process Design & Computerized Process Monitoring and Control

No further information

10.) Human Factors/Behavioral

No further information

11.) Use of Absorption Chillers (**www.gasairconditioning.org** and www.seascolumbia.edu)

Low-pressure, steam-driven absorption chillers are available in capacities ranging from 100 to 1,500 tons. Absorption chillers come in two commercially available designs: single-effect and double-effect. Single-effect machines provide a thermal COP of 0.7 and require about 18 pounds of 15-pound-per-square-inch-gauge (psig) steam per ton-hour of cooling. Double-effect machines are about 40% more efficient, but require a higher grade of thermal input, using about 10 pounds of 100- to 150-psig steam per ton-hour.

A single-effect absorption machine means all condensing heat cools and condenses in the condenser. From there it is released to the cooling water. A double-effect machine adopts a higher heat efficiency of condensation and divides the generator into a high-temperature and a low-temperature generator.

Hot water absorption chillers often use a heat byproduct from other industrial processes that might otherwise go unused. An example of this type application of hot-water absorption is the PSM Print Shop in Lake Forest, California, where a 40-ton absorption chiller is used to cool printing press components.

Another example of industrial applications of absorption is the F. B. Manion Company in Manchester, Connecticut, where a 15-ton gas-fired absorption system is used for cooling water in a grinding shop serving the automotive and aerospace industry. At the Foster Company in Dayville, Connecticut, gas-fired absorbers provide cooling water for plastics processing operations, and at NE Electronics in Milford, Connecticut, over 100 tons of absorption units provide cooling for electronics manufacturing.

12.) Engine Idle Controls and Automatic Shutoff Controls (www.1.eere.energy.gov)

Reduced Engine Idling

- Direct-fire heaters provide heating only to the cab and/or the engine, and have been available for many years. Common in marine applications, they use a small combustion flame to supply heat through a heat exchanger.

- An auxiliary power unit (APU) is mounted externally on the truck cab and consists of a small combustion engine equipped with a generator and heat recovery to provide electricity and heat. Electricity from the APU can be used to power an air-conditioning unit for the cab and sleeper. APUs also have the advantage of continuing to heat in case of an engine breakdown while not draining battery power.

- Automatic engine idle systems start and stop the truck engine automatically in order to maintain a specified cab temperature, or maintain minimum battery voltage. Drivers typically activate the system in the evening and program a desire temperature range, then the engine will start and shut off automatically in order to run heating or air conditioning.

Refer to the section entitled “The Transportation Sector: Defining Its Scope And Constituents” for further information regarding engine idling and automatic shutoff controls.

13.) Hybrid Cooling

No further information

14.) Waste Heat Recovery/Waste to Energy/Fuel (www1.eere.energy.gov)

Making Energy from Waste

If waste-to-energy (WTE) power plants are considered a relatively more expensive energy option than coal-fired and other power generation plants, why has China—a developing nation of 1.3 billion people known to spend frugally on its public infrastructure—built 39 of them? "The Chinese are looking at their long-term interests," notes Earth and Environmental Engineering Professor Nickolas Themelis, director of the Earth Engineering Center (EEC) at the Earth Institute and a leading innovator of waste-to-energy technologies. "They see the value in recovering energy from waste, and increasing the utilization of energy while reducing green-house gas emissions and the acreage required for landfill."

According to the Waste-to-Energy Research and Technology Council, founded by EEC and the only research arm of companies and municipalities operating WTE facilities, WTE plants have significant environmental benefits, including:

- Conserving fossil fuels by generating electricity and heat; One ton of combusted municipal solid waste (MSW) reduces oil use by about 45 gallons, and coal use by about 0.28 tons.

- Reducing greenhouse gas emissions: One ton of MSW combusted rather than landfilled reduces greenhouse gas emissions by 1.2 tons of carbon dioxide.

Recovering ferrous and non-ferous metals.

According to the integrated Waste Services Association, there are 09 waste-to-energy plants operating in the U. S. managing about 13 percent of the country's trash.

- Reducing the space required by landfills in addition, these plants do not have the aqueous emissions that may be produced by landfills.

New ways of intensifying the WTE process are leading to more cost-effective plant designs. "Whereas the United States has 90 large WTE plants usually at some distance away from cities, Denmark has built over 30 smaller facilities to serve its population of 3 million, so that each plant is within a town or city and provides district heating, as well as electricity," says Themelis. "We are interested in learning more about the costs and benefits of developing WTE plants in this manner, as it may have implications for urban centers in developing countries with growing energy needs."

Graduate students at Columbia, under the direction of Professor Marco Castaldi, are conducting research on the reaction phenomena of rubber and plastics gasification; others are working on several projects related to integrated waste management and the advancement of the WTE alternative to landfilling.

15.) Emerging Technologies/New Developments (www1.eere.energy.gov)

Chemicals

- Affinity Ceramic Membranes with CO_2 Transport Channels
- Improved Methods for the Production of Polyurethane Foam
- Process Heater Ultra-Low Excess Air Control
- P-Xylene Production with Waste Heat Powered Ammonia Absorption Refrigeration

Forest Products

- Black Liquor Steam Reforming/Pulsed Combustion
- Borate Autocausticizing
- Directed Green Liquor Utilization (D-Glu) Pulping
- Screenable Pressure Sensitive Adhesives
- Surfactant Spray to Improve Flotation Deinking Performance
- Use of Residual Solids from Pulp and Paper Mills for Ready-Mixed Concrete

Glass

- Advanced Oxy-Fuel-Fired Front-End System
- Optimization of On-Line Coating of Float Glass

Metal Casting

- Lost Foam Casting Quantifier Program
- ZSP Tooling and Rapid Prototyping in Die Casting

Mining

- High-Temperature Superconductors in Underground Communications
- Improving Taconite Processing Plant Efficiency

Steel

- High-Quality Iron Nuggets Using a Rotary Hearth Furnace
- Life Improvement of Pot Hardware in Continuous Hot-Dipping Processes
- Optimization of Post-Combustion in Steelmaking
- Steel Foam Materials and Structures
- Submerged Entry Nozzles that Resist Clogging

Crosscutting

- Carbon Films for Next Generation Rotating Equipment Applications
- Diagnostics and Control of Natural Gas Fired Furnaces via Flame Image Analysis

- Diode Laser Sensor for Combustion Control
- Fiber-Optic Sensor for Industrial Process Measurement and Control
- Hybrid Integrated Model for Gas Metal Arc Welding
- Portable Parallel Beam X-Ray Difraction System
- Process Heater System
- Super Boiler
- Tube Metal Temperature Sensor
- Ultra-Nanocrystalline Diamond Coatings (UNDC)

16.) Commericialized Technologies (www1.eere.energy.gov)

Agriculture

- Utilization of Corn-Based Polymers

Chemicals

- Pressure Swing Adsorption for Product Recovery Forest Products
- Continuous Digester Control Technology

Metal Casting

- Die Casting Copper Motor Rotors

Steel

- Electrochemical De-Zincing of Steel Scrap
- Transfer Rolls for Steel Production

Crosscutting Technology

- Advanced Turbine System
- Forced Internal Recirculation Burner
- In-Situ, Real-Time Measurement of Melt Constituents
- Solid-State Sensors for Monitoring Hydrogen

Mining

- Fibrous Monolithic Composites as Wear-Resistant Components

Integration of CO_2 capture with advanced power cycles and technologies and with environmental control technologies for criteria pollutants.

17.) Available Tools/Resources (www1.eere.energy.gov)
It is noteworthy that a wealth of software tools and other resources are available from the DOE Energy Efficiency and Renewable Energy website. Some of these software offerings are as follows:

- AIRMaster+
- Chilled Water System Analysis Tool (CWSAT)
- Combined Heat and Power Application Tool (CHP)
- Fan System Assessment Tool (FSAT)
- MotorMaster+ 4.0
- MotorMaster+ International
- NOx and Energy Assessment Tool (NxEAT)
- Plant Energy Profiler for the Chemical Industry (ChemPEP Tool)
- Process Heating Assessment and Survey Tool (PHAST)
- Pumping System Assessment Tool 2004 (PSAT)
- Steam System Tool Suite